Water Management With Conservation Tillage[1]

P.W. Unger[2], C.J. Gerard[3], J.E. Matocha[4],
F. M. Hons[5], D.G. Bordovsky[6], and C.W. Wendt[7]

Introduction

Plant water stress is a common problem in arid and semiarid regions. Additionally, water stress due to short term droughts can severely limit crop yields in subhumid and even in humid regions. Each of the above climatic regions occurs in Texas, but research to develop practices to minimize the adverse effects of water deficiencies has been conducted mainly in the semiarid and subhumid regions, with a limited amount being conducted in the humid regions. In arid regions, water stress is alleviated mainly by irrigation.

One practice that has received much attention for erosion control in recent years and that also has water conservation benefits is conservation tillage. Conservation tillage means different things to different people. However, a commonly accepted definition of conservation tillage is any tillage system that leaves at least 30 percent of the soil surface covered with residues after a crop is planted. Another definition is "any tillage sequence that reduces loss of soil or water relative to conventional tillage; often a form of non-inversion tillage that retains protective amounts of residue mulch on the surface" (SCSA, 1982). The latter definition does not require surface residues to be present, but both definitions recognize the value of surface residues for reducing soil and water losses. We will use the more restrictive definition, namely, that surface residues be present, at least for a major part of the crop production cycle (harvest to harvest). For this report, the objectives were to review the effects of conservation tillage under various cropping conditions in Texas with respect to water conservation and use of the water for crop production. First, we will discuss the results from studies at the humid and subhumid locations, then from studies at semiarid locations in the state.

Humid and Subhumid Locations

Humid and subhumid locations at which conservation tillage research has been conducted are the College Station area, Corpus Christi, Temple, Munday, and Chillicothe. At these locations, the emphasis frequently was on factors other than water conservation and/or management, hut some results pertaining to water are available from the studies.

A study was initiated by Hons (unpublished data) in 1983 on a Ships clay-Weswood silt loam intergrade in Burleson County (near College Station) to determine the effect of tillage and cropping sequence on crop yields and nitrogen fertilizer uptake efficiency. Cropping sequences evaluated included grain sorghum-wheat-soybean, wheat-soybean, and continuous monocultures of sorghum, wheat, and soybeans. The sorghum-wheat-soybean sequence produced three crops in two years, while the wheat-soybean double-crop sequence produced two crops each year. Each monoculture resulted in one crop each year. Tillage and no-tillage treatments were compared. Neutron attenuation was used in 1985 to determine the water use by soybeans in each of the cropping sequences. The 1985 cropping season was much drier than normal and severely retarded pod development in late August and September. Yields in 1985 were about 50 percent to 60 percent of those achieved in 1984. A significant tillage x cropping sequence interaction for yield was observed in 1985 (Table 1). Tillage treatments did not significantly influence yields in any of the cropping sequences except for continuous soybeans, where yields were higher with conventional tillage than with no-tillage. Tillage and cropping sequence also significantly interacted to influence soybean water use efficiency (Table **1).** No-tillage soybeans exhibited greater water use efficiencies in the sorghum-wheat-soybean and wheat-soybean sequences than conventional tillage soybeans. Tillage had no effect on water use efficiency in monocrop soybeans, possibly because of the small quantlty of residue produced by this sequence. No-tillage soybeans in the sorghum-wheat-soybean sequence exhibited the greatest water use

TABLE 1. TILLAGE AND CROPPING SEQUENCE EFFECTS ON SOYBEAN YIELDS AND WATER USE EFFICIENCY, BURLESON COUNTY, TEXAS, 1985

Cropping sequence	Tillage treatment	Yield	Water use efficiency
		$Mg\ ha^{-1}$	$kg\ m^{-3}$
Sorghum-wheat-soybean	No-till	1.79 b'	**0.81** a
	Conventional	**1.83** ab	0.76 b
Wheat-soybean	No-till	1.73 bc	0.71 c
	Conventional	1.58 c	**0.60** d
Continuous soybean	No-till	1.61 c	**0.60** d
	Conventional	1.97 a	**0.64** d

'Column values followed by the same letter or **letters are not significantly different at the 5% probability level.**

[1]Contribution from USDA-ARS, Bushland, Texas, and TAES, Vernon, Corpus Christi, College Station, Munday, and Lubbock, Texas.

[2]Soil scientist, USDA-ARS, Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland, TX 79012.

[3] Professor, TAES, Vernon.

[4] Professor, TAES, Corpus Christi.

[5] Associate professor, TAES, College Station.

[6] Research scientist, TAES, Munday.

[7] Professor, TAES, Lubbock.

[8]This paper reports the results of **research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U.S. Department** of **Agriculture or the Texas Agricultural Experiment Station nor does it imply registration under FIFRA as amended.**

efficiency, followed by conventional tillage soybeans in this sequence. The third greatest efficiency was produced by no-tillage soybeans in the wheat-soybean sequence, with all other crop sequence and tillage combinations giving statistically equal results. Efficiencies appeared to increase with increasing residue in the system. Conventional tillage soybeans in the wheat-soybean sequence and both tillage treatments with monocrop apparently did not result in sufficient residue to significantly improve water use efficiency.

Matocha (unpublished data) evaluated the effects of conventional, minimum, and no-tillage treatments on soil water contents, and corn and grain sorghum yields at Corpus Christi. Starter fertilizer and insecticide [carbofuran—(2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate)][8] treatments were evaluated also. Soil water contents were determined either at the period of peak demand by the crop or at crop harvest, but differences among treatments generally were slight. Grain yields generally were lower, significantly so in two cases, with no-tillage than with the other tillage treatments (Table 2). The yield decreases were attributed to increased weed pressure.

On the same soil, Matocha and Bennett (1984) compared two forms of conservation tillage with conventional, deep chisel, and deep moldboard tillage systems for cotton production over a six-year period. Glyphosate [N-(phosphomethyl) glycine] and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) were used in separate applications in the no-tillage system, while paraquat alone was used in the minimum-tillage system. Soil water content measurements in the fall season showed substantial improvement in rainfall harvesting as a result of primary deep tillage. However, treatment effects on soil water content at planting and during the growing season were minimal. Lint production in minimum- and no-tillage systems equalled or exceeded yields of other systems in four out of five seasons (a hurricane destroyed one harvest). Fiber quality values were largely unchanged by tillage treatments.

At Temple, where annual precipitation averages 840 mm, Gerik and Morrison (1984) obtained similar soil water storage and sorghum grain yields by using no- and conventional-tillage treatments on an Austin silty clay soil. Although water storage and yields were not significantly affected by the treatments, no-tillage has potential for the region because of lower production costs and because it permits using narrow rows for sorghum, which has potential for higher yields. Using narrow rows is impossible with clean tillage because the sorghum must be cultivated for weed control. Also on the Austin soil at Temple, wheat yields in a three-year study with wide beds were not significantly different in two years but were significantly lower with no-tillage in a droughty year because of less tillering (Gerik and Morrison, 1985).

At Munday in the Rolling Plains, Bordovsky (unpublished data) compared reduced and conventional tillage for grain sorghum production. For reduced tillage, glyphosate was used to control weeds between harvest and planting, and cultivation controlled weeds during the growing season. Conventional tillage consisted of disking twice, bedding, and cultivating before planting plus additional cultivating after planting. For both tillage methods, herbicides were used for growing season weed control. The treatments for non-

TABLE 2. EFFECT OF TILLAGE SYSTEM, STARTER FERTILIZER, AND/OR SOIL INSECTICIDE ON GRAIN YIELDS OF CORN OR GRAIN SORGHUM ON ORELLA SANDY CLAY AT CORPUS CHRISTI, TEXAS, IN 1983 AND 1984

Crop, year, and treatment	Grain Yield			
	Tillage System			
	Conventional	Minimum	No-Tillage	LSD (0.05)
	Mg ha^{-1}			
Corn—1983				
Tillage only	3.33	2.94	2.15	0.78
Tillage + Fert. + Insect.	3.14	3.38	2.60	NS[1]
Corn—1984				
Tillage only	4.24	4.10	4.00	NS
Tillage + Insect	3.38	3.53	2.80	0.63
Sorghum—1983				
Tillage only	4.00	4.21	3.90	NS
Tillage + Insect	4.52	4.75	4.96	NS
Sorghum—1984				
Tillage only	2.12	2.14	2.40	NS
Tillage + Fert. + Insect.	2.89	2.28	2.14	0.64

[1]NS = not significant.

irrigated sorghum had no significant effect on grain yield, water use, or water use efficiency. Grain yields for five years averaged 2.59 and 2.56 Mg ha^{-1} with conventional and reduced tillage, respectively. Under irrigated conditions, continuous grain sorghum yields with reduced tillage and clean tillage averaged 4.75 and 4.60 Mg ha^{-1} for the respective treatments. As for yields, differences in water use and water use efficiency were not statistically significant under irrigated conditions.

Also at Munday, irrigated wheat yields were significantly lower with reduced than with clean tillage for one crop out of four (5.86 vs. 4.46 Mg ha^{-1}) and averaged 4.13 Mg ha^{-1} with clean tillage and 3.48 Mg^{-1} with reduced tillage (Gerard and Bordovsky, 1984). The lower yields with no-tillage resulted from a decreased number of heads, which possibly resulted from fewer plants due to planting problems in large amounts of surface residues and/or reduced tillering.

Clark (1983) reported the results of a tillage study conducted on an Abilene clay loam at Chillicothe in the Rolling Plains Resource Region, in which diked, alternate row diked, and non-diked treatments for conventional- and reduced-tillage systems were compared. Rainfall was 85 percent of normal. The tillage systems did not significantly influence cotton yields, but furrow diking before the spring planting resulted in significant yield increases (Table 3). Diking alternate furrows or every furrow resulted in yield increases of 16 percent and 36 percent, respectively.

Semiarid Locations

Conservation tillage research in semiarid Texas has been conducted at Bushland and Lubbock, where annual precipitation averages about 470 mm, with most of the precipitation occurring during May to September. Conservation tillage research involving dryland, irrigated, and irrigated-dryland cropping systems has been evaluated at the semiarid locations.

Dryland Systems

Apparently, the first conservation tillage system used in Texas on dryland was stubble mulch tillage, which was first used at Bushland in the early 1940s. This tillage method, which undercuts the surface to control weeds and retains most crop residues on the surface, was initially introduced to control wind erosion. It proved highly effective for controlling erosion provided sufficient residues were available. This, however, was not always the case, and soil-roughening tillage sometimes was needed to enhance erosion control. Where sufficient residues were available, water conservation as well as soil conservation benefits from stubble mulch tillage were soon realized. However, because of limited residue production by non-irrigated crops in the semiarid region of Texas, water conservation and wheat yields with stubble mulch tillage were only moderately greater than with clean tillage. Based on a long-term study (1942-1969), plant-available soil water contents at wheat planting averaged 91 and 103 mm with clean (one-way disk) and stubble mulch tillage, respectively. Grain yields averaged 0.59 and 0.69 Mg ha-l with the respective tillage methods for continuous wheat (Johnson and Davis, 1972).

Fallowing is primarily used in semiarid regions, with a major objective being increased water storage in soil for use by a subsequent crop. Fallowing is most successful on soils that have a large water storage capacity but that generally are not filled to capacity during the interval between crops because of limited precipitation, low infiltration rates, and/or high evaporation rates. These conditions prevail on some of the major soils in the semiarid region where fallowing is most prevalent in Texas.

In the long-term dryland study at Bushland, plant-available soil water content at wheat planting averaged 154 mm with stubble mulch and 128 mm with clean tillage in a wheat-fallow system. Grain yields averaged 1.06 and 0.93 Mg ha' with the respective treatments (Johnson and Davis, 1972). However, water storage and yields with either tillage method for the fallow system were not doubled as compared with those for the continuous wheat system. Because yields on a total area basis were lower with the wheat-fallow system, this system is not considered as suitable for the semiarid region of Texas as it is for the Central and Northern Great Plains, where yields generally are doubled by fallowing. From an economic viewpoint, it may be satisfactory because fewer planting and harvesting

TABLE 3. YIELD RESPONSE OF COTTON TO TILLAGE TREATMENTS AT CHILLICOTHE, TEXAS, 1981 (FROM CLARK, 1983)

Tillage system	Subsoiling depth	Lint yield: Furrows diked: None	Alternate	All	Average
	m	Mg ha^{-1}			
Conventional	—	**0.214**	**0.294**	**0.314**	**0.274** a
Reduced	**1.0**	**0.255**	**0.261**	**0.314**	**0.277** a
Reduced	**0.5**	—	**0.259**	**0.330**	**0.294** a
Average		**0.234** c[1]	**0.271** b	**0.319** a	

[1]Means within a row or column followed by the same letter are not significantly different at the 5% probability level.

operations are involved and because it reduces the risk of crop failure.

No-tillage retains more residues on the surface than stubble mulch tillage, but early results from ongoing studies on dryland for annually cropped wheat or grain sorghum indicate that no-tillage is less satisfactory than stubble mulch tillage for these crops at Bushland from a yield viewpoint (personal communication, O.R. Jones). Possible factors involved include residue phytotoxicity, inadequate weed control, herbicide carry-over, increased runoff (after sorghum) due to surface sealing, and inadequate fertility. Again, the economics of the systems must be compared to assess the suitability of these systems for a given situation.

An unusual form of residue management is the use of cotton bur or gin trash mulches to control wind erosion on sandy soils in cotton-producing areas of West Texas. Besides controlling erosion, precipitation storage is also increased by the mulches. At Big Spring on Amarillo sandy clay loam, the gain in soil water was about 40 percent as surface coverage increased from 0 percent to 100 percent (Fryrear and Koshi, 1971). Full coverage was achieved with about 11.0 Mg ha^{-1} of mulch. Water storage efficiencies were 41 percent, 58 percent, and 73 percent for the 0, 11.2, and 22.4 Mg ha^{-1} gin trash treatments, respectively. Precipitation averaged 337 mm in 1968 and 1969. Soil water content was increased to a 3-m depth, and cotton lint yields averaged 197, 260, and 282 kg ha^{-1} with the respective treatments.

Fallowing in Texas generally involves winter wheat, either in a one-crop/two-year (wheat-fallow) or a two-crop/three-year system. In the latter, winter wheat is grown in rotation with a summer crop. As indicated above, the wheat-fallow system generally is considered unsuitable for Texas from a water storage and grain yield viewpoint but may be suitable economically. The low effectiveness is attributed, in part, to its long (about 16 months) fallow period. For this system, most water storage occurs during the first summer after wheat harvest with little additional storage during the second summer. As a result, precipitation storage efficiency for the system is low. A more effective system with respect to water storage and total production is a wheat-fallow-sorghum-fallow system of two crops in three years (Unger, 1972), which has a fallow period of about 11 months between each crop. Under dryland conditions, however, even this system resulted in relatively low precipitation storage and/or crop yields, regardless of tillage method used (clean, stubble mulch, or no-tillage) (Wiese and Army, 1958; Wiese et al., 1960; Wiese et al., 1967). As for annual cropping, water conservation and crop yield benefits from conservation tillage as compared with clean tillage in the semiarid region of Texas were low because of low residue production by dryland crops.

The fact that low residue amounts were a major factor contributing to low water storage and crop yields under dryland conditions was illustrated by Unger (1978), who placed wheat straw at various rates on Pullman clay loam at Bushland after wheat harvest (start of fallow). Water storage, subsequent sorghum grain yields, and precipitation use efficiencies were more than doubled by the high residue treatments (8 and 12 Mg ha^{-1}) as compared with the no-residue treatment (Table 4). While applying crop residues to large areas may not be practical in all situations, crops such as irrigated wheat often produce more than 6.0 Mg ha^{-1} of residues, which could enhance water storage and crop yields when they are managed on the soil surface by suitable conservation tillage techniques.

Systems Involving Irrigation

Annual cropping with full irrigation generally results in the highest total production. However, the Ogallala aquifer, which supplies water for irrigation in the semiarid region of Texas, is being depleted, and the cost of irrigation (pumping water) has increased greatly in the last 10 to 15 years. Consequently, much research has been conducted in recent years to develop alternatives to full irrigation of annual crops. The goal has been to make more effective use of precipitation in the cropping system.

When irrigated wheat was followed by 11 months of fallow and grain sorghum was grown with or without irrigation, water storage from precipitation was increased, which reduced the amount of irrigation water required and/or increased sorghum grain yields. In a study by Musick et al. (1977), precipitation storage efficiencies during fallow after wheat were 35 percent and 21 percent with no-tillage and clean tillage, respectively, on level bordered plots, and 47 percent and 28 percent with no-tillage and clean tillage, respectively, on graded furrow plots. Because of the greater water storage, sorghum yields on level bordered plots averaged 5.10 Mg ha^{-1} with no-tillage and 4.08 Mg ha^{-1} with

TABLE 4. MULCH RATE EFFECTS ON SOIL WATER STORAGE DURING FALLOW, SORGHUM GRAIN YIELDS, AND PRECIPITATION USE EFFICIENCY, BUSHLAND, TEXAS, 1973-1976 (FROM UNGER, 1978)

Mulch rate	Precipitation storage[1]	Grain yield	Precipitation use efficiency[2]
Mg ha^{-1}	mm	Mg ha^{-1}	kg m^{-3}
0	**72** c[3]	**1.78** c	**0.32** c
1	**99** b	**2.41** b	**0.44** b
2	100 b	**2.60** b	**0.46** b
4	**116** b	**2.98** b	**0.53** b
8	**139** a	**3.68** a	**0.67** a
12	**147** a	**3.99** a	**0.77** a

[1]Fallow period precipitation averaged 318 mm. Storage determined to a 1.8-m depth.

[2]Based on grain yield divided by total precipitation from start of fallow to end of sorghum growing season plus net soil water depletion.

[3]Column values followed by the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range Test).

disk tillage when 150 mm of growing season irrigation water was applied. With 300 mm of irrigation, the respective yields were 6.46 and 5.97 Mg ha^{-1}. On graded furrows, yields averaged 5.42 Mg ha^{-1}, with an average of 169 mm of irrigation water retained on no-tillage plots and 4.26 Mg ha^{-1} with 93 mm of irrigation water retained on disk-tillage plots. The higher yields on no-tillage plots resulted from greater water storage during fallow and enhanced irrigation water infiltration during the growing season. The latter occurred even though the disk-tillage plots contained less water than no-tillage plots at sorghum planting time.

In attempts to further enhance precipitation use for sorghum production, Unger and Wiese (1979)and Unger (1984) followed irrigated winter wheat with a fallow period, then grew grain sorghum without irrigation. The irrigated wheat produced an average of about 8 Mg ha' of residue. In the study by Unger and Wiese (1979), 15 percent, 23 percent, and 35 percent of the fallow-period precipitation was stored as soil water with disk-, sweep-, and no-tillage treatments, respectively, and sorghum grain yields averaged 1.93, 2.50, and 3.14 Mg ha^{-1} for the respective treatments. Precipitation storage during fallow averaged 29 percent, 34 percent, 27 percent, 36 percent, and 45 percent for moldboard-, disk-, rotary-, sweep-, and no-tillage treatments, respectively, in the study by Unger (1984). Grain yields with the respective treatments averaged 2.56, 2.37, 2.19, 2.77, and 3.34 Mg ha^{-1}.

Baumhardt et al. (1985) evaluated the irrigated wheat-fallow-grain sorghum rotation at Bushland and at Lubbock. Disk- and no-tillage treatments were used during the fallow period. Water storage tended to be or was significantly greater with no-tillage at Bushland but was similar for both tillage treatments at Lubbock. At Lubbock, the soil was more permeable and shallower; thus, precipitation more readily filled the soil profile with water regardless of tillage method. Without irrigation, sorghum grain yields were significantly greater with no-tillage than disk tillage in both years at Bushland but in only one year at Lubbock. With irrigation, grain yields were significantly greater with no-tillage at Lubbock but not at Bushland.

Besides grain sorghum, crops evaluated in rotation with irrigated winter wheat at Bushland were sunflower and corn. In the system with sunflower, average increases in soil water during fallow after wheat were 38, 53, 61, and 71 mm with disk-, sweep-, limited-, and no-tillage treatments, respectively. Seed yields of the non-irrigated sunflower ranged from 1.23 (for sweep and limited tillage) to 1.38 (for no-tillage) Mg ha^{-1}, but the differences were not significant (Unger, 1981). In the study with corn, grain yields were lower with no-tillage due to a severe nitrogen deficiency in one year, even though analyses before planting indicated that the soil contained sufficient nitrogen. The next year when nitrogen fertilizer was applied, yield differences were not statistically significant. Water use was not significantly affected by tillage method the first year but was significantly lower with no-tillage as compared with disk or sweep tillage the second year (Unger, 1986).

Using conservation tillage for annually irrigated crops often is difficult because of planting problems in heavy residues and because of poor weed and volunteer plant control. These problems may be especially severe when crops such as wheat, corn, or grain sorghum are grown continually. In such cases, limited- rather than no-tillage systems generally have been most successful.

A study at Bushland by Allen et al. (1976) evaluated the effects of limited, clean, and no-tillage on furrow-irrigated winter wheat. The limited and no-tillage treatments were alternated annually. For no-tillage, weed and volunteer wheat control with herbicides was satisfactory in two years but required a second application of a contact herbicide in the third year because of above-average rainfall. No-tillage seeding with a conventional grain drill also was satisfactory in two years. In the third year, variable plant populations resulted from limited disk opener penetration because of high amounts of surface residues (about 10 Mg ha^{-1}). For limited tillage, satisfactory weed and volunteer wheat control was obtained with herbicides [2,4-D-(2,4-dichlorophenoxy) acetic acid] and tillage (disk bedding and sweep-rod weeding). Tillage as needed gave satisfactory control in clean-tillage plots. With both the limited- and conventional-tillage treatments, seeding and plant establishment were satisfactory each year.

Irrigation water advance in the residue-covered no-tillage and the clean-tillage furrows gave no problems. Average water infiltration for three years was significantly higher with clean than with limited or no-tillage, under both limited and adequate irrigation conditions, but no-tillage resulted in significantly higher yields than clean tillage with limited irrigation and non-significant differences with adequate irrigation. Irrigation water use efficiency was significantly higher with no-tillage than with clean tillage with both irrigation levels.

Because of less severe problems with limited tillage, Allen et al. (1976) considered this method (actually, alternating between limited tillage and no-tillage) a more practical and dependable alternative than no-tillage to clean tillage for continuous irrigated wheat production. Unger (1977)reached the same conclusion from a study at Bushland, in which irrigated and dryland wheat were alternated. and disk-, sweep-, and no-tillage treatments were evaluated. Yields after two years of no-tillage declined compared to those with other tillage methods but exceeded those with other tillage methods when these plots were tilled before establishing the fourth crop.

In a two-year study for continuous irrigated grain sorghum at Bushland, average grain yields were similar following clean- or no-tillage seeding. For the first crop, residues from a previous grain sorghum study were present. Residues in the furrow of no-tillage plots slowed irrigation water advance and increased water penetration depth and storage compared with clean tillage. No problems occurred when irrigating the first no-tillage crop, but some bed-furrow maintenance was needed before irrigating the second crop. Also, uncontrolled volunteer sorghum resulted in higher forage production but lower grain yield (Allen et al., 1975a). Because of difficulty in controlling volunteer plants, a system of continuous no-tillage is considered impractical for grain sorghum under conditions at Bushland unless "safened" seed is used. Volunteer problems were encountered also for continuous no-tillage corn (Fowler, 1972).

Although no-tillage may be impractical for continuous grain sorghum, favorable results have been obtained with limited tillage for that crop at Bushland. A study by Allen et al. (1980) showed that a mulch-subsoil treatment (limited tillage) consisting of applying anhydrous ammonia in the furrow by subsoiling 0.20 m deep in the fall, and sweep-rod weeding and planting in the spring resulted in significantly higher yields (5.92 vs. 5.16 Mg ha^{-1}) and irrigation water infiltration (386 vs. 347 mm) than clean tillage under limited irrigation conditions. With adequate irrigation, yield (6.86 vs. 6.35 Mg ha^{-1}) and infiltration (483 vs. 437 mm) differences were not statistically significant. Differences in water use efficiency with both irrigation levels were not statistically significant.

In a study involving irrigated grain sorghum double-cropped after wheat, no-tillage seeded sorghum emerged sooner, grew taller, and matured up to five days earlier than sorghum seeded after clean tillage. Sorghum was irrigated for emergence on both tillage areas all years except in 1972, when timely rainfall occurred after planting. For the five-year study, grain yields averaged 5.69 Mg ha^{-1} with no-tillage and 5.07 Mg ha^{-1} with clean tillage. Because of the higher yields and no difference in total water use, water use efficiency averaged higher with the no-tillage treatment (Allen et al., 1975b).

Summary

In semiarid regions of Texas, water deficiencies limit crop yields, which in turn, in many cases, result in inadequate amounts of crop residues to enhance infiltration and reduce evaporation. Hence, yields of annual crops in these situations generally were not or were only slightly enhanced by conservation tillage. At more humid locations, crop yields again were little affected by conservation tillage when weed control was satisfactory because the higher rainfall level provided generally adequate water with all tillage systems. The higher residue amounts with higher crop yields may have contributed to the lower yields in some cases, as at Corpus Christi, because of greater problems of weed control under high residue conditions. Consequently, improved weed control and/or residue management systems are needed to make conservation tillage more acceptable for annual cropping in the subhumid and humid regions of Texas.

Where water is available for adequate irrigation, similar yields generally have been obtained, regardless of tillage system employed, provided weed control and planting were adequate. This is because irrigation largely negates the water conservation benefits of conservation tillage. In contrast, conservation tillage often enhances yields under limited irrigation conditions because of the water conserved from precipitation.

Fallowing in Texas is used primarily in the semiarid western part of the state. One of its purposes is to increase soil water storage for a subsequent crop. However, under dryland conditions, residue amounts generally are too low for conservation tillage practices to greatly enhance water infiltration and/or suppress evaporation. Increased water storage and crop yields have been obtained when residues from irrigated crops have been managed by conservation tillage methods. An irrigated wheat-fallow-grain sorghum cropping system, with sorghum grown with or without irrigation, has been particularly suitable for the semiarid region of Texas. In this region, water for irrigation is limited and being depleted, soils have adequate capacity to store a large part of fallow period precipitation, and sorghum responds well to the stored water under limited irrigation or dryland conditions.

Some crop production problems regarding conservation tillage have not been solved, but conservation tillage has potential for conserving water and/or enhancing crop yields, especially in the drier regions of the state. Increased water conservation will have a major impact on maintaining crop production at satisfactory levels when the irrigation water supply further declines and when irrigated-dryland or dryland cropping systems become more common. Satisfactory crop production under such conditions will have a major impact on maintaining the economic viability of the major crop-producing area of West Texas. It also will strengthen the economic viability of other crop producing areas of the state. Although this report did not pertain to soil conservation, conservation tillage is widely recognized as being highly effective for conserving the soil. Hence, increased adoption of conservation tillage for water conservation and/or crop yield benefits also will enhance soil conservation and, thereby, result in increased compliance with erosion control regulations.

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